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Scanning distortions and misregistration in the Peto-Scott 3-plumbicon colour camera

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THE BRITISH BROADCASTING CORPORATION
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SUMMARY

An investigation was undertaken into the types of geometrical distortion encountered in a large number of scanning yokes used in the Philips/ Peto-Scott 3-plumbicon colour cameras. The relative geometric distortions, or misregistrations, between yokes were also investigated, together with the feasibility of using these measurements to select groups of 3 yokes with similar characteristics to form matched triads.

1. INTRODUCTION

With the delivery of, and subsequent experience with, the first Peto-Scott colour cameras, it became evident that problems were likely to be encountered with registration errors of a type that could not be corrected with the existing camera controls, these controls being horizontal and vertical shifts, linearity, rotation and 'skew.'

The errors under consideration were of the type which result in departures from parallelism in either the horizontal or vertical planes, and are commonly known as pincushion and keystone distortions (Fig. 1). They were observed both as absolute geometrical errors and as relative errors between colour-separation channels, causing, in the latter case, varying degrees of misregistration. It seemed probable that, while the differences between yokes were due to tolerances in their manufacture, and possibly to their optical misalignment, a large proportion of the absolute geometrical error in each channel could be attributed to the lens; this part of the error would, of course, be identical in all three channels. An investigation was therefore instigated into the factors affecting picture geometry and, from the methods of measurement so developed, it became possible to undertake a programme of yoke selection which in most cases resulted in a notable improvement in the registration capabilities of the cameras.

2. GENERAL

First, a method of measuring the geometry of the display was developed, and this was used to measure both the absolute distortion of the scanned picture and the relative distortions or misregistrations between the channels.

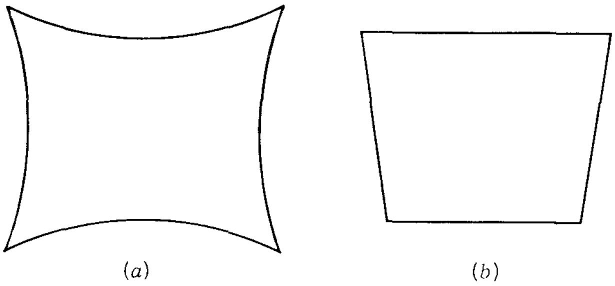


Fig. 1 - Geometric distortions
(*a*) pincushion
(*b*) keystone

Secondly, the results of the measurements were plotted in a convenient form which facilitated comparison between yokes and, from these measurements, a programme of selection of matched groups of 3 yokes was attempted.

Thirdly, the lens aberrations were determined by an optical method and this enabled the total measured distortion to be corrected so as to yield a figure for the yokes alone.

Finally, the effect of heat on a yoke was investigated since it had been suggested that the gradual heating up of the interior of the camera body might produce a progressive change in picture geometry.

3. EXPERIMENTAL DETAILS

3.1. General Requirements

Since departures from horizontal and vertical parallelism were to be observed, it was considered that a convenient yardstick against which comparison could be made would be an electronic grille pattern which, in this case, consisted of twenty-one vertical bars and nineteen horizontal bars. A special test chart was then drawn up which, when viewed by a perfect camera, would produce a signal identical to that of the electronic pattern. Direct comparison could thus be made between the electronic pattern and the camera picture by arranging that they were simultaneously displayed on the same monitor.

An additional facility was provided which enabled a 'difference' technique to be used in the comparison between the camera and electronic patterns, by inverting the polarity of either of the two signals. If the amplitudes were equalized, then clearly the conditions for perfect registration would be the complete cancellation of the two patterns. In practice, different effective line thicknesses prevented this ideal situation. Small misregistrations were then detectable as narrow black and white lines, while the complete separation of the patterns implied somewhat larger errors. This method also had the advantage of indicating at a glance the direction of the misregistration.

3.2. Measurement of Horizontal Errors

The terms horizontal and vertical misregistration occur frequently in this report and, since these terms have given rise to some confusion in the past, it is felt that a short explanation of this terminology would not be out of place. Horizontal misregistration refers to a relative displacement in a horizontal direction of a point on a vertical line and vertical misregistration likewise refers to the relative shift in a vertical direction of a point on a horizontal line.

Horizontal misregistration was measured by introducing either a positive or negative delay into the signal from the green channel. A 'negative' delay was achieved by switching in all the available delay, and then re-registering the centre of the picture, using the horizontal shift control on the green channel; any delay which was then removed could be regarded as negative.

Errors were measured by switching in an increasing delay until the lines being measured were coincident at the point of measurement. The degree of misregistration could then be expressed directly in nanoseconds. Attention is drawn to the experimental layout shown in Fig. 2.

3.3. Measurement of Skew Errors

If there is any error in the relative angle of orientation of the horizontal and vertical scan coils, the condition known as skew will arise. The effect on the picture will be to make the angle between the horizontals and verticals deviate from 90°. While a certain degree of overall skew may be tolerated, it was found that some yokes displayed excessive degrees of skew and it was considered necessary to measure this effect. Differences in skew between green and the other channels may be eliminated by adjustment of the skew facility which had been provided on the red and blue channels of the camera; this introduces a controlled amount of cross-talk from the vertical scan circuits into the horizontal scan circuits and thus achieves a cancellation of the relative skews. The facility is not, however, provided on the green channel.

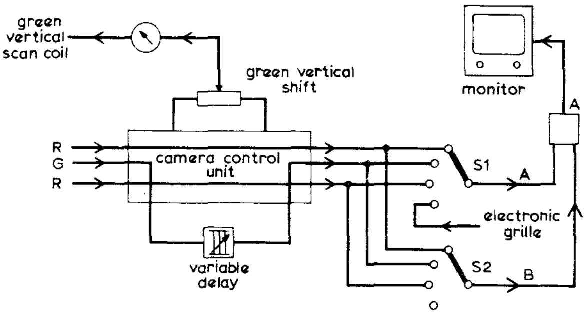


Fig. 2 - Experimental layout, block diagram

Skew was measured by recording the horizontal shifts of the picture verticals with respect to the true verticals at the top, centre, and the bottom of the picture. The method of measurement was the same as that used for horizontal misregistrations.

3.4. Measurement of Vertical Errors

The approach to the problem of measuring vertical errors was somewhat different. It would clearly have been most impracticable to introduce delays of multiples of one line in order to perform an operation similar to that used in the measurement of horizontal errors. The vertical shift control supplies a deflection current to the vertical scan coils and it seemed reasonable to suppose that the shift produced would be linearly related to the current supplied. This suggested that the vertical shift control could be used as a means of obtaining an equivalent to vertical delay, while the current being supplied to the scan coils could be monitored as a measure of vertical error. In order to compare the horizontal and vertical readings directly, the vertical shift current had to be calibrated in 'effective nanoseconds (vertical)'; the 'effective nanosecond' is defined as 'that shift in the vertical plane which is equal in distance to the horizontal shift corresponding to a signal delay of one nanosecond.'

The vertical shift current was first calibrated in terms of numbers of picture lines; this was done by shifting the picture through, say, 20 lines and noting the corresponding change in shift current.

This current could then be expressed in effective nanoseconds by using the relationship

$$\text{Vert Shift (eff.ns (vert))} = \frac{\text{Shift (no. of lines) x Aspect ratio x Line period } (53\,\mu\text{s}) \text{ x } 10^3}{\text{Total no. of picture lines (572)}}$$

3.5. Notes on Camera Line Up

The measurement of large numbers of yokes in one camera involves a great deal of mechanical work in removing yoke mounts from the camera, removing tubes, head amplifiers etc., and then replacing them with the set of yokes to be measured. For consistency of results it is clear that particular care has to be taken to ensure that all parameters which could possibly affect registration are kept constant, or at least subject to a minimum variation. These factors will be considered separately.

(a) Tubes

It is known that the picture geometry may be slightly affected by rotating a tube in its mount. Changes in alignment of the electron beam can occur, and there is a possibility that slight variations might exist in the mesh which, of course, rotates as the tube rotates. The orientation of each tube about its axis was therefore always carefully noted so as to ensure that no rotation of the tube occurred as a result of removing and replacing it.

(b) Optical Alignment of Camera

It is important that the camera should be optically aligned. Optical alignment implies the condition in which the lens, the dichroic splitter, and the tubes in their mounts all lie symmetrically about the optical axis. If any one of the yoke mounts deviates in any way from this condition, a lesser or greater degree of picture distortion will result and this will generally be of the keystone type and will be accompanied by differential defocussing across the picture. In practice a certain degree of non-alignment had to be tolerated as optical alignment is a tedious process which was inconvenient to perform before every set of measurements. Its effects were minimized, however, by using the same set of aligned yoke mounts for all measurements. In spite of these precautions, variations in alignment were observed from yoke to yoke even in the same mount and this became a significant source of experimental error.

(c) Lens

A considerable variation in the degree and even in the type of lens distortion was observed with different zoom settings.

Since such a variation would have rendered measurement meaningless, particular care was taken to ensure that the same lens setting was used in each series of measurements.

3.6. Lens Abberations

A detailed description of the experimental details involved in measuring the lens is outside the scope of this report. Nevertheless it was clear that the lens had to be measured at the zoom setting used for the yoke measurements. The results were processed to yield horizontal and vertical errors at the same points chosen for the overall measurements on the yokes, in order that direct comparison could be made. The results are discussed in 4.1.

3.7. Effect of Heat

It had been suggested that one factor which might have been responsible for registration drift in cameras was the gradual heating up of the camera body, particularly under the thermal insulation provided by Outside Broadcast camera covers. In order to determine whether heat could have any effect at all, it was decided to exaggerate the effect (if any) by heating a yoke up to 60°C, in an oven, and then noting any change in the camera reproduction of the test pattern with respect to the electronic pattern. No such change was ever found, however, and it was therefore decided not to pursue this line of investigation any further.

3.8. Measurement Procedure

As yokes were received for measurement, those which did not arrive as sets were grouped into arbitrary sets of three. The measurements made on each set of yokes were as follows. The green signal was displayed on the monitor with respect to the electronic pattern and the green channel distortions were measured in absolute terms. The red and blue channels were then registered with green as well as they could be, within the limits of the adjustments available, and the red/green and blue/green misregistrations were measured; this indirectly also yielded the absolute distortions of the red and blue channels. This method of measurement was chosen because errors of registration are frequently an order of magnitude less than the overall geometrical errors.

It would have been impracticable to measure both the horizontal and the vertical misregistrations at each intersection of a horizontal and vertical line in the grille pattern, neither was it necessary to do so. Measurements were confined, therefore, to the intersections of those lines in the grid which are shown thickened in Fig. 3, which also illustrates the relationship of the measurement points with zonal regions 1, 2 and 3. For the purpose of recording results a chart was drawn up containing only the lines which intersected at the measurement points, and the appropriate readings were entered at the points of intersection.

3.9. Yoke Selection

Since many measurements have to be taken into consideration when selecting a set of matched yokes it was impossible to assess all the measurements simultaneously. A simplified quick-reference chart was therefore drawn up. This is illustrated in Fig. 4 and shows the red, green and blue horizontals at the top, centre, and bottom of the picture on a scale chosen to exaggerate the misregistration errors between them; attention is drawn to the green centre and edge verticals which were also plotted as an indication of inherent skew in the picture. The example shows actual measurements made on a set of yokes as supplied by the manufacturer. It will be seen that not only are the misregistration errors excessive but a considerable degree of skew is also present in the green yoke. It must be stressed, however, that this example was chosen to illustrate the worst problems that are likely to be encountered and it does not necessarily represent a typical set of yokes.

It will be observed that no indication of horizontal misregistration is included. It was found that, although the situation could arise in which there was good vertical registration and poor horizontal registration, the reverse was usually the case and a very good indication of the overall registration could be obtained by observing the vertical misregistration only. This seemingly better horizontal performance arises from the fact that in a misregistration which increases symmetrically from the centre of the picture, the degree of misregistration encountered at the extremes of any line, whether it be horizontal or vertical, depends on:

(a) the distance of the line from the centre,

(b) the length of the line

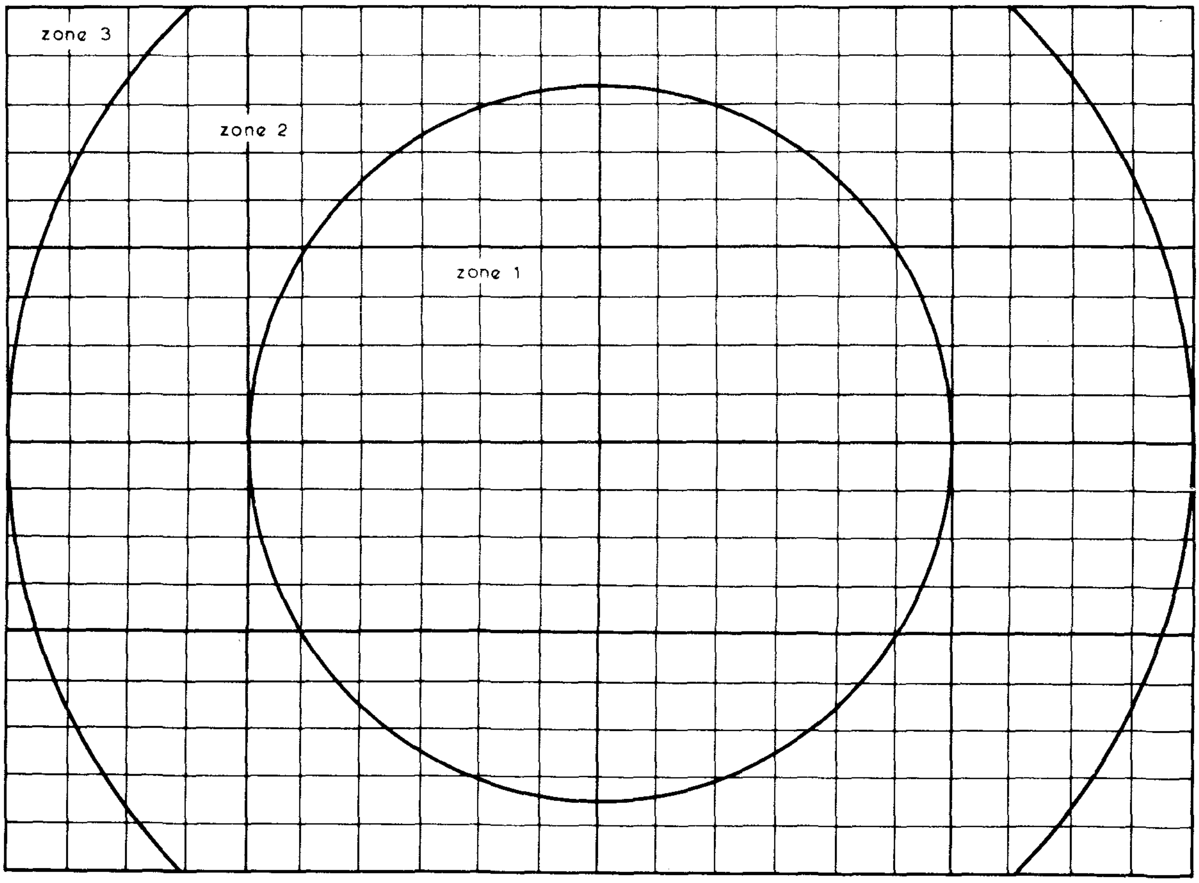


Fig. 3 - Grille pattern. Measurement points are at the intersection of the thick horizontals and verticals, and are shown in relation to zonal regions 1, 2, 3

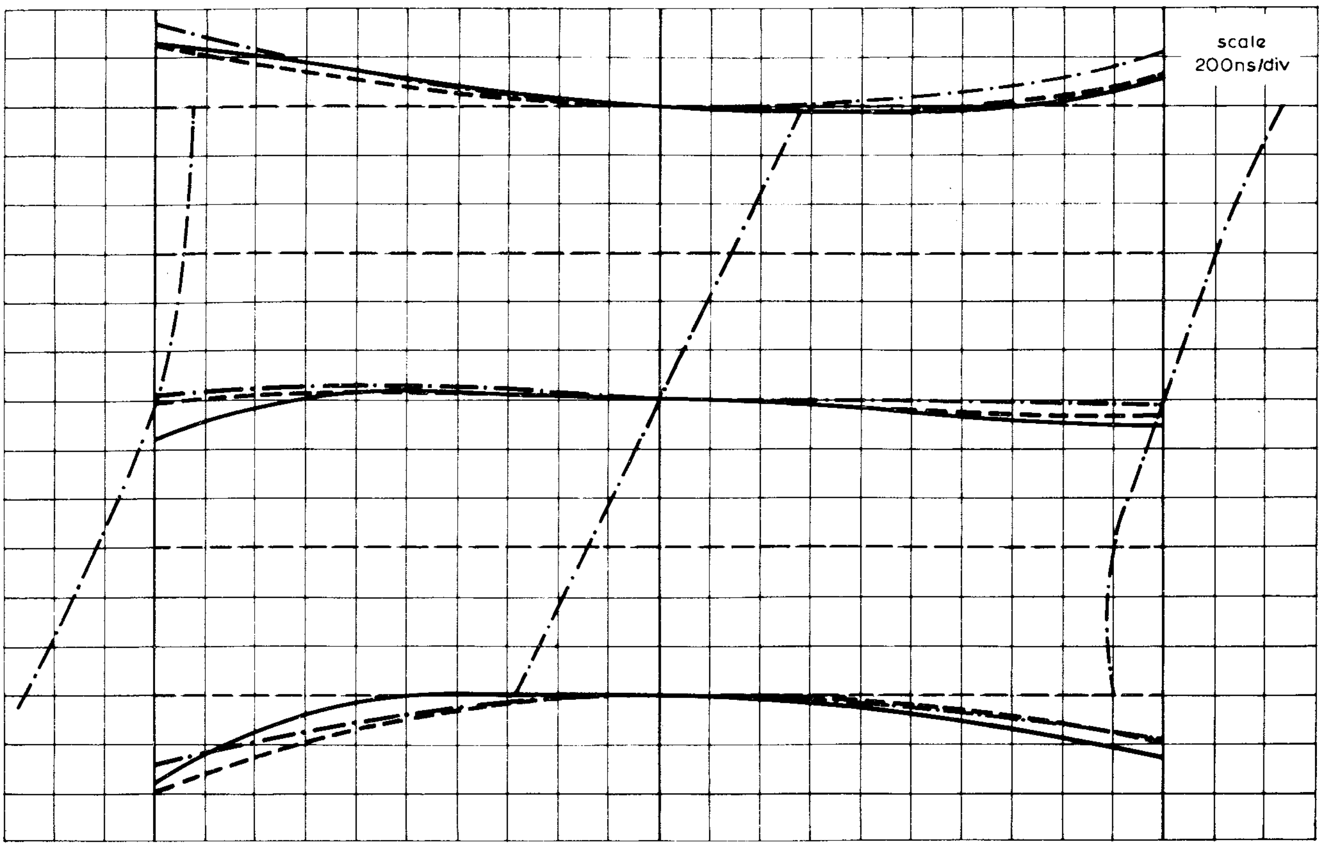


Fig. 4 - Before regrouping. Quick-reference chart for a poorly-matched set of yokes

———— red
— — — — blue
- —— - —— green

The relative importances of (a) and (b) depend entirely on the law governing the relationship between distance from the centre and deviation from true geometry.

In the case we are considering (b) was relatively more important than (a); consequently the top and bottom horizontal lines, in spite of their closer proximity to the centre, usually suffered greater degrees of misregistration at the edges. It goes without saying, however, that no set was passed as satisfactory without a check on horizontal errors.

It was unfortunately not possible, because of experimental inaccuracies, to select matched sets of yokes purely from the measurements already described. These measurements could only be used as a guide as to which yokes were the most likely to form matched groups. It was not unusual to find that in a predicted set of three, only two yokes were sufficiently closely matched to be acceptable and a further search would then have to be made for a suitable third yoke. Nevertheless, the process of selection was neither excessively difficult nor time-consuming.

As a rule, yokes were rejected if their extreme errors were:

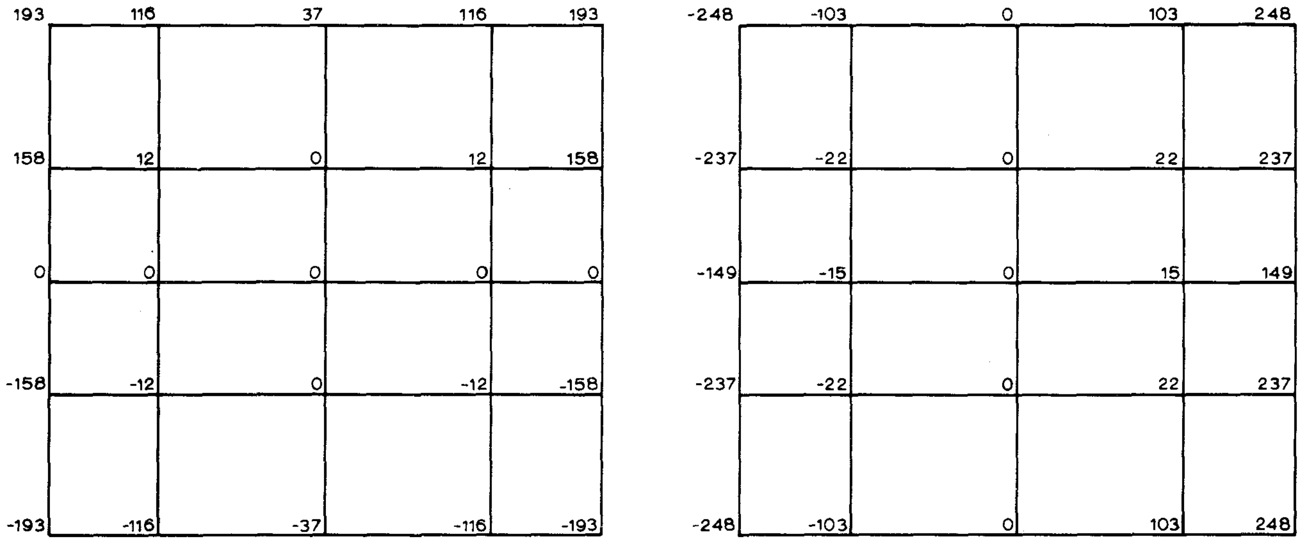
at the edge of Zone one

Red/green > 20 ns
Blue/green > 20 ns

in Zone three

Red/green > 50 ns
Blue/green > 100 ns

The tolerance chosen for blue/green misregistration is somewhat lower in view of the low luminance contribution of blue.



(a)

(b)

Fig. 5 - Geometric distortions due to the lens

(*a*) vertical component expressed in effective nanoseconds (vertical)

(*b*) horizontal component expressed in effective nanoseconds (horizontal)

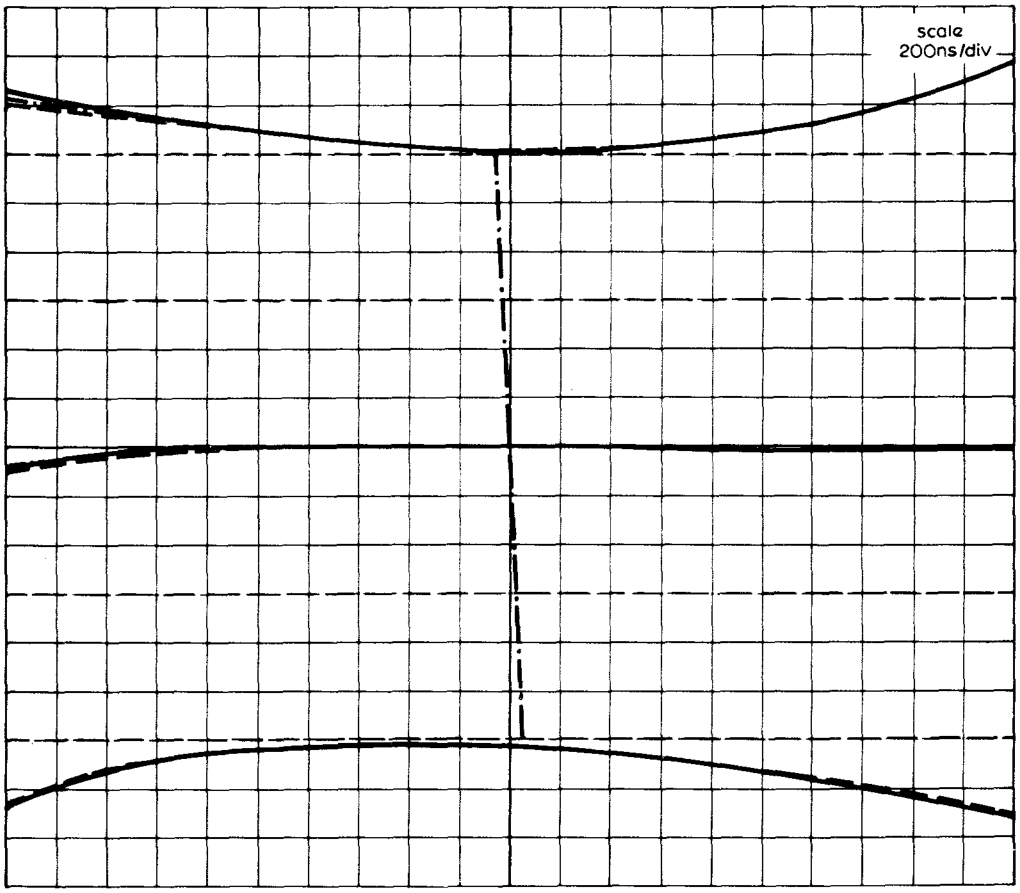


Fig. 6 - After regrouping. Chart showing the typical degree of matching that was obtained

———— red

— — — — blue

—— – —— green

4. DISCUSSION OF RESULTS

4.1. Contribution by Lens Towards Overall Distortion

The measured errors attributed to the lens are tabulated in Fig. 5. This shows a pincushion distortion with a vertical component in the corners of 193 effective ns, or 156 effective ns if the height distortion of 37 effective ns is ignored. While measuring the yokes, this height error could not be seen because of the ambiguity in the correct setting of the vertical scan amplitude. Measurements of distortion could therefore only be made relative to the centre of each horizontal or vertical. From the yoke records available, it has been calculated that the mean vertical pincushion distortion was 322 effective ns, hence the mean inherent vertical distortion due to the yokes corresponds approximately to 166 effective ns in each corner.

4.2. Registration Measurements and Regrouping

Any sets of yokes which did not fall within the limits of registration quoted in 3.9 were rejected and the component yokes were tested in other sets. It is interesting to note that, out of the 22 sets initially measured, only 6 were acceptable as they stood. This corresponds to a rejection rate of approximately 73%.

Fig. 6 shows the registration diagram for a fairly typical set of suitably sorted yokes. The improvement in registration achieved by re-grouping may be gauged by comparing it with Fig. 4, bearing in mind that the example quoted in Fig. 4 is somewhat worse than average.

5. CONCLUSION

In spite of the difficulties involved in maintaining the same experimental conditions for each yoke measured, so as to minimize experimental errors, a method has been developed of measuring yokes with sufficient accuracy to be of assistance in selecting new groups of yokes. This programme has now been extended to cover all the Peto-Scott cameras at present being installed in studios and Outside Broadcast units.

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